

A MODELING APPROACH TO IDENTIFY DRAINAGE SOLUTIONS FOR DOWNTOWN COLUMBUS, GEORGIA

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ABSTRACT. Downtown Columbus is bordered on the west and south by the Chattahoochee River and by Weracoba Creek on the east. In many areas, the existing combined sewer system lacks the capacity to drain the highly urbanized area. In addition, the adjacent Weracoba Creek currently overflows into the low lying downtown area, increasing the threat of flood hazards on the already inadequate system. In order to investigate the behavior of the existing combined sewer system and to evaluate proposed improvements to mitigate localized flooding and flooding induced by Weracoba Creek, a comprehensive XP-SWMM model of the downtown area and the adjacent Weracoba Creek was developed.

The modeling approach began with extensive field work to develop as-built maps of the existing combined sewer system to determine drainage structure locations, elevations, pipe configurations and invert data. A total of seventy six drainage sub basins were delineated and input into the model in conjunction with one hundred and six existing pipes. In addition to the complex pipe system, the model incorporates seven combined sewer overflow structures along the Chattahoochee River and a portion of Weracoba Creek that flows through an existing half mile long box culvert adjacent to downtown Columbus.

The XP-SWMM model was calibrated by comparing the locations identified to flood in the model with actual recorded flood events using the 2, 10 and 25 year frequency storms. Currently, the model is being used to evaluate improvements to the existing combined sewer system and improvements to Weracoba Creek to reduce flood hazards in the downtown area for the 25 year design storm. The model will enable the design team to develop a strategic long range stormwater master plan to control flood hazards for the City of Columbus.

INTRODUCTION

Downtown Columbus is drained by a combined sewer system that has evolved over the past century to accommodate the increasing demands of urbanization. The combined sewer system discharges into seven combined sewer overflow structures located along the Chattahoochee River that divert the dry weather flows to the treatment plant and the overflows to the Chattahoochee River. A secondary treatment facility located at 4th Street treats overflows from

low intensity storms before being discharged to the river. Areas reported to flood frequently, indicate that reaches of the existing system do not have the capacity to drain the runoff generated by the basin, causing the lines to surcharge, forcing the water to be stored on the surface.

Weracoba Creek drains the residential neighborhoods in the rolling hills upstream of downtown Columbus. The creek flows south, through the City, intersecting with a number of major highways and entering a half mile long triple box culvert to pass through the downtown area. The water surface levels along Weracoba Creek have increased dramatically as the cumulative effect of urbanization has increased the total volume of runoff draining to the creek. Currently, storm events exceed the channel banks and flow overland, into the low lying down town area, increasing the threat of flood hazards. The intent of this paper is to describe the modeling approach developed to study the behavior of the existing combined sewer system in downtown Columbus and the additional flood impacts resulting from Weracoba Creek. A comprehensive XP-SWMM model was developed to simulate the existing combined sewer system in the downtown area. HEC -1 and HEC-2 were used to obtain flow rates and water surface elevations for Weracoba Creek to define the flood impacts from various frequency storms.

MODELING APPROACH

Preparing a detailed computer model, representing the actual hydrologic and hydraulic characteristics of downtown Columbus was essential for analyzing this complex urban storm drainage system. The model provides a quantitative framework for synthesizing a large set of factors that describe the spatial variability of the existing system combined with various hydrologic parameters. Computer models require calibration to assure that they produce reasonable results that approximate a set of field measurements or results that are consistent with targets identified to reflect actual field conditions. In the absence of detailed rainfall data, flow measurements or water surface elevations, the model is considered verified if it identifies flooding locations with magnitude and frequency that match actual reported surface flooding locations. After the model has been calibrated it is used to identify pipes that are inadequate for various frequency

storms and to evaluate proposed improvements to the combined sewer system.

Data Acquisition/Model Set-Up

In order to develop a model reflective of actual field conditions, extensive field work was performed to determine as-built conditions for the existing combined sewer system. Pipe connections were traced by observing flow intensity and direction and conventional dye testing methods were used when necessary. The as-built structure and pipe data, combined with the GIS base mapping supplied by the City of Columbus served as the basis for the development of the XP-SWMM model. One hundred and six existing pipes were input into XP-SWMM, representing the existing pipe network. Study points (nodes) and pipe reaches were assigned a logical identifier to be used throughout the development of the project.

Drainage Sub-basin Delineation

Downtown Columbus is relatively flat, making it difficult to define drainage boundaries based on topographic information. Instead, the as-built base map of the existing combined sewer system was used to delineate sub-basins based on the configuration and flow path of the existing pipe system as shown in Figure 1. The area of each sub-basin was computed using Auto-CAD and input into the XP-SWMM model. The methods described in the Soil Conservation Service, Hydrology for Small Watersheds, Technical Release (TR-55) was used to determine curve numbers and lag times for input into the XP-SWMM model.

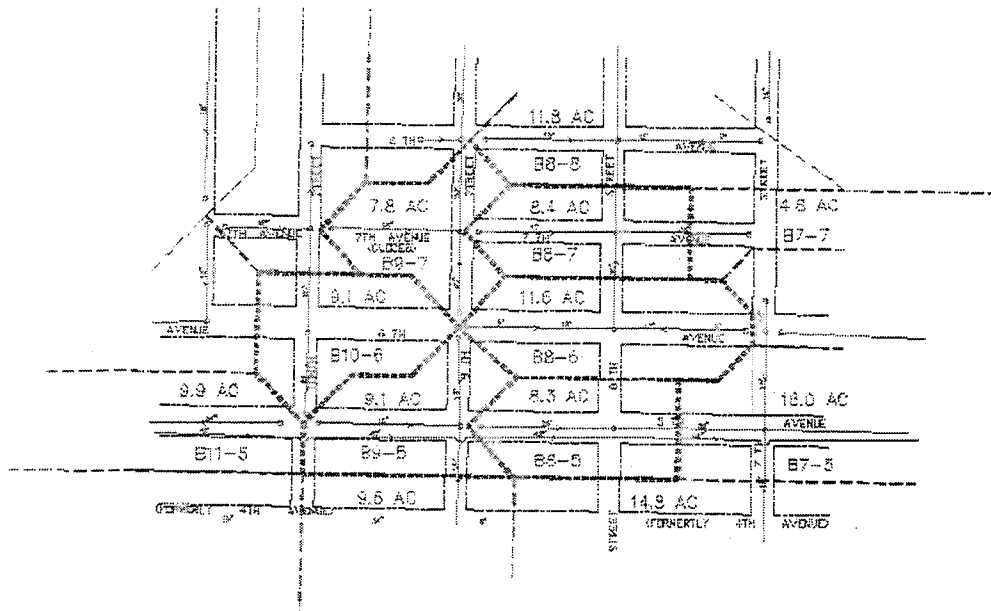


Figure 1. Drainage sub-basin delineation for downtown areas

Combined Sewer Overflow Structures

One of the most critical elements in the set-up of the XP-SWMM model was to simulate the behavior of seven combined sewer overflow structures along the Chattahoochee River that divert dry weather flows to the treatment plant and peak flows to the river. These structures, referred to as diversion structures are connected by a 72 inch pipe that transports dry weather flows to the treatment plant located in southwest Columbus on the Chattahoochee River. The downtown area is drained by a set of tributary pipes that discharge to one of the seven diversion structures. Design drawings were obtained for each of the combined sewer overflow structures to determine critical weir elevations needed to accurately model the behavior of the diversion structures.

In addition to the seven flow diversion structures, a secondary treatment plant located at 4th Avenue was constructed to provide additional water quality benefits by treating a range of overflows resulting from low intensity storms that produce overflows but are well below peak flow levels. Figure 2 below shows the pipe network flowing to the secondary treatment facility at 4th Avenue as set up in the XP-SWMM model. Two diversion structures located upstream of the secondary treatment facility, divert dry weather flows to the treatment plant, peak flows to the river and flows from low intensity storms to the secondary treatment for screening and disinfection before being discharged to the Chattahoochee River. A critical element in the set up of the model was the appropriate set up of the junction structures and the secondary treatment facility.

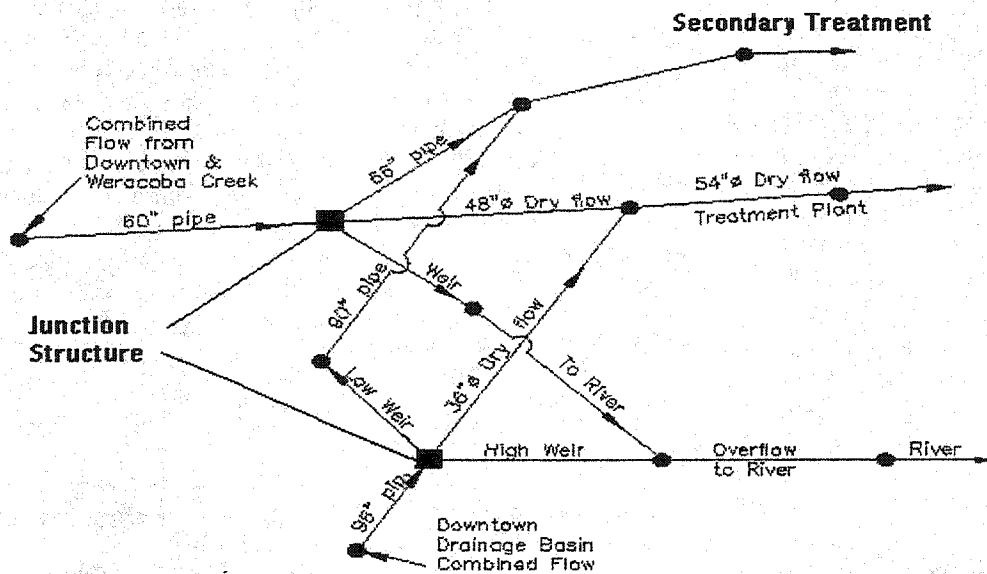


Figure 2. XP-SWMM model setup for secondary treatment facility at 4th Avenue

The incoming 60 inch and 90 inch pipes shown above, each connect to a junction structure with three different weir elevations to separate the flow. One weir diverts dry weather flows to the treatment plant, one weir diverts low flows to the secondary treatment facility, and the third weir, set at a

much higher elevation diverts peak flows to the Chattahoochee River. Figure 3 shows the diversion of the three different flow stages incoming to the junction structure as simulated in the XP-SWMM model.

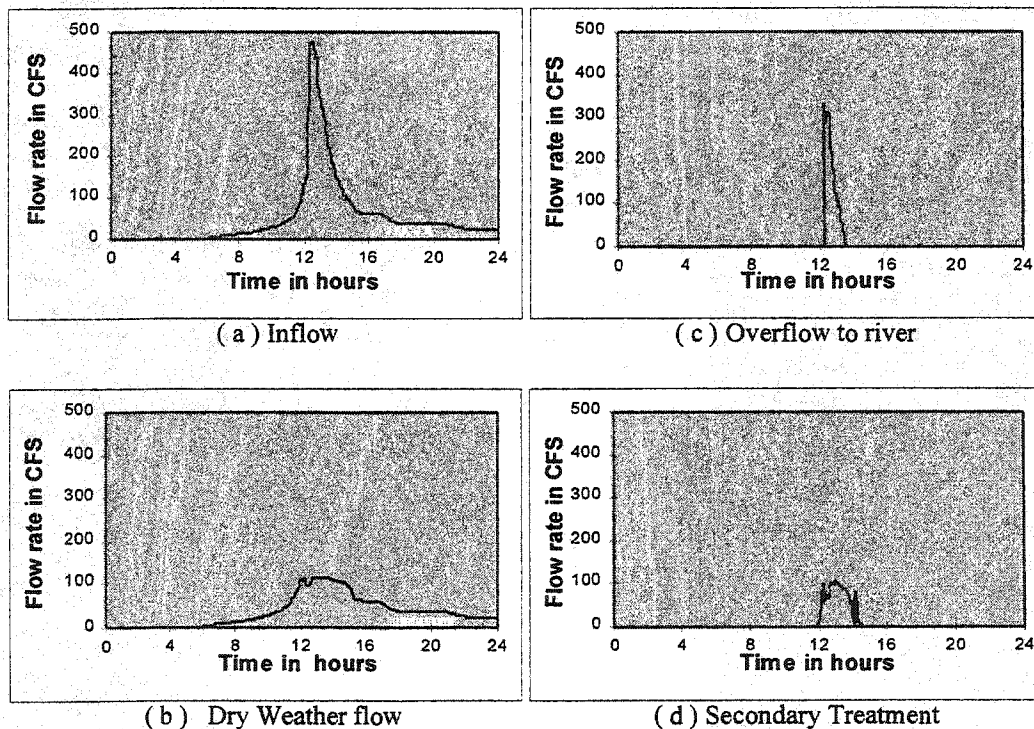


Figure 3. Junction structure upstream of 4th Street Secondary Treatment Plant diverts three stages of flow.

Weracoba Creek

Weracoba Creek is an example of a natural stream that has been transformed into an urban channel characterized by a number of flow restricting bridges and culverts. The triple box culvert located at Wynnton Road, adjacent to the downtown area receives run off from a 4 square mile area of the Weracoba Creek watershed. The HEC-1 flow rate and the HEC-2 water surface elevation at the entrance to the box culvert verify that Weracoba Creek has the capacity to only transport the 2 year frequency storm. For storm events greater than the two year storm, Weracoba Creek exceeds the channel banks and flows overland through the streets into the low lying downtown area, increasing the threat of flood hazards on the inadequate system. In order to evaluate the behavior of the existing combined sewer system in downtown Columbus, a portion of Weracoba Creek was included in the modeling approach.

The Wynnton Road box culvert was input into the XP-SWMM model, with the upstream flows entered as a single hydrograph. The resulting flow rate and hydrograph shape generated by XP-SWMM was calibrated by comparing it with the flow rate and hydrograph generated by HEC-1. The Weracoba Creek basin upstream of Wynnton Road has a time of concentration of approximately 80 minutes. Due to the high speed flow paths in the concrete pipes found in the downtown system, the downtown basin has a time of concentration less than 15 minutes. The difference in lag times, suggests that the downtown system is draining the tail portion of the downtown hydrograph when peak flows arrive from Weracoba Creek. As a result, for a short, intensive rainfall event, the low lying downtown area may be flooded twice within a short period of time.

Chattahoochee River

When the Chattahoochee River reaches the City of Columbus, the river is transporting the runoff generated by 4,670 square miles of watershed. The total flow length of the Chattahoochee River from the upstream reaches in north Georgia to the City of Columbus is over 257 miles, with dam control at West Point Lake, 37 miles upstream of Columbus. The peak flow rate generated by the upstream reaches of the Chattahoochee River takes approximately 2.7 days to reach the City of Columbus, creating the possibility for a another rainfall event to hit Columbus at the same time the peak is arriving on the Chattahoochee River. The water surface elevation in the Chattahoochee River for the 10 year

frequency storm identified in the City of Columbus Flood Insurance Study, dated May 3, 1993, is considerably lower than the invert elevation in the existing sewer system in the down town area, indicating that the river is not a threat to the downtown area for the 10 year storm. However, if a severe storm hits downtown at the same time the Chattahoochee River peaks, the river may have backwater effects on the seven diversion structures and the combined sewer pipe that connects them. Currently, the Chattahoochee River is treated as a backwater boundary condition using the 10 year storm water surface elevation, while the downtown drainage improvements will be designed for the 25 year frequency storm.

CONCLUSIONS

The model developed for the hydrologic and hydraulic study of the existing combined sewer system in downtown Columbus has identified surface flooding locations for various design storms consistent with those locations recorded to actually flood. The primary function of the model was to simulate the behavior of the existing combined sewer system and to identify proposed improvements for the 25 year design storm to relieve flooding resulting from the inadequate drainage system and from Weracoba Creek overflows. Various combinations of improvements will be modeled to identify the combination and sequence of improvements that produce optimum benefits for the City of Columbus.

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